ABSTRACT

Optimization of Cherenkov Detectors for Fast Timing

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As we continue to push the frontiers of accelerator design, we open up the possibility of observing more energetic particle interactions. However, observation of these interactions requires incredibly precise and accurate measurements. At the forefront lies the Large Hadron Collider (LHC), which will collide two 7 TeV proton beams. A proposed addition to the Compact Muon Solenoid experiment at the LHC, the high precision spectrometer (HPS), will probe interactions in which two protons scatter off of each other at very small angles, correlating to a small (< 5%) fractional loss of momentum. This process will look deeply into particle interactions and may expose new physics, including Higgs boson production and events outside of the Standard Model. To identify the scattering vertex, and thus determine which protons were involved in the same scattering events, the proton detectors must have a timing resolution on the order of picoseconds. Cherenkov detectors have been experimentally shown to have timing resolutions as low as 15 ps, which could be optimized through simulation. This study models quartz Cherenkov detectors to find the optimal configuration for producing the best timing resolution. The study used two programming languages based on C++: Geant4 to model the passage of particles in matter, and ROOT for analysis and modeling the photodetector. The simulation predicts the timing resolution of a quartz radiator leading to a silicon photomultiplier (SiPM) in the beamline to be a few picoseconds. However, this study has not yet been able to replicate the experimental data. The simulated number of photoelectrons in the detector was consistently higher than the experimentally measured value. An experimental study would be needed to determine whether this loss of photoelectrons occurs in the quartz crystal, at the interface of the crystal with the photodetector, or at the photodetector itself. The simulated timing resolution has also been consistently better than the experimental value by a factor of two to five, accounting for the electronics, which have a timing resolution of 3-4 ps. Nevertheless, the study indicates that Cherenkov detectors are an excellent choice for fast timing detectors, though further investigation needs to be done to confirm the causes of the inefficiencies in the actual detector.